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OCCUPATIONAL LASER HAZARDS -  
A SURVEY OF THE LITERATURE

7 July 1965

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**AUTONETICS**  
A DIVISION OF NORTH AMERICAN AVIATION, INC.



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**ABSTRACT**

The need for guidelines to protect personnel involved in laser research is generally recognized. The literature reveals, however, that views differ as to what precautions should be required. This bibliography contains 48 entries arranged alphabetically by author, and includes papers published in the open literature and reports which may be obtained through the Defense Documentation Center. The period of time covered is from 1956 through May 1965.

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## INTRODUCTION

In 1960, Dr. Theodore H. Maiman announced the development of the optical maser, or as it is commonly called, the laser. The possibilities of this device have lead to intensive biological, medical, and technical research.

It was assumed in the early stages of research that exposure to laser radiation would present hazards to personnel involved in its operation. However, after five years, information is still inconclusive as to exposure to a single laser flash or to possible cumulative effects over long periods. Reports have been made concerning eye injuries but it is not known exactly how the eye was damaged. It is generally agreed that safety measures are necessary but views differ as to what precautions should be required.

This bibliography was compiled to cite such information as is presently available. The 48 references consist of papers published in the open literature and of reports which may be obtained through the Defense Documentation Center. The period of time covered is from 1956 through May 1965.

Acknowledgment is made to Mr. E. A. Port who contributed references and to Dr. J. W. Moyer under whose direction this search was instituted.

1. CONFERENCE ON BIOLOGIC EFFECTS OF LASER RADIATION (1st)  
WELCOME ADDRESS. Joe M. Blumberg. (Armed Forces  
Inst. of Pathology, Army Medical Center, Washington,  
D. C., 1964, 1 p., UNCLASSIFIED REPORT) AD 612 443

Descriptors: (\*Pathology, Lasers), (\*Lasers,  
Pathology), Wounds and injuries, Burns, Symposia.

2. EYE-PROTECTIVE DEVICES. Dr. Andrew J. Britten. Tank  
Fire Control Division, Frankford Arsenal, Philadelphia,  
Pa. (Ordnance, November-December, 1964, pp. 312-3.5)

Because of the hazard to eyes viewing nuclear  
explosions or impinged upon by laser beams, antflash  
eye-protective devices are being developed both for  
optical instruments and the men who employ them.

3. LASERS AND THEIR EFFECTS. James H. Burkhalter. (Martin-  
Marietta Corp., Contract DA49 193MD2456, Annual  
progress rept., 1 July 63 - 1 Mar. 64, April 1,  
1964, rept. no. OR3885, 54 p.) AD 433 218

Descriptors: (\*Lasers, Biology), Instrumentation,  
Heat Exchangers, Lenses, Damage, Calorimeters, Bio-  
logical laboratories, Paramagnetic resonance, Design,  
Electrons, Spin, Measurement, Power supplies, Circuits,  
Electronics, Radiation damage, Radiation effects,  
Temperature, Cryogenics.

4. LASERS AND THEIR EFFECTS. James H. Burkhalter. (Martin  
Marietta Corp., Contract DA49 193MD2456, Annual  
rept., 1 Mar. 64 - 1 Mar. 65, April 1, 1965, 57 p.)  
AD 460 174

A description is given of the work performed by  
the Martin Company Research Laboratories for the  
Biological Effects of Lasers Program. This includes  
developmental work on a subcutaneous shock sensor,  
a beam sampling system, a new type of laser output  
coupler and other devices, and investigations into  
the techniques of passive Q-switching.

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5. BIOLOGICAL EFFECTS OF LASERS: SAFETY RECOMMENDATIONS  
AND A COMMENT ON THE CONCEPT OF OCULAR DAMAGE.

P. A. Circincione. (Naval Training Device Center,  
Port Washington, New York, July 28, 1964, report  
no. NAVTRADEVCECEN 1H15) AD 607 718

Descriptors: (Lasers, Burns), (Safety, Lasers),  
Vision, Eye, Safety, Ophthalmology, Blindness, Retina,  
Tissues (Biology), Necrosis, Skin, Pathology, Humans,  
Eyeglasses.

6. GUIDELINES TO SAFE LASER WELDING. Roswell G. Daniels.

Preventive Medicine Div., Office of the Surgeon  
General, Dept. of the Army, Washington, D. C.

There is no question but that exposure to laser  
radiation may present a serious health hazard to  
man. Although additional research remains to be  
accomplished to quantitate dose-response relation-  
ships, and to assess some of the variables influ-  
encing this hazard, definite safety measures are  
necessary today -- not tomorrow.

Recognizing that immediate guides for control of  
exposure to laser radiation were necessary, the  
Occupational Health Branch of the U. S. Army has  
formulated some general tentative guidelines for  
handling lasers.

7. LASERS AND MASERS -- HEALTH HAZARDS AND THEIR CONTROL.

Roswell G. Daniels and Bernard Goldstein. Office  
of the Surgeon General, Department of the Army,  
Washington, D. C. (Federation Proc., Vol. 24,  
no. 1, Pt. III, January-February, 1965, pp. S-27-  
S-30, refs.)

The object of this paper is to delineate many  
variables involved in tissue damage caused by ex-  
posure to laser and maser sources, and to present an  
acceptable interim control program. For this assess-  
ment it is appropriate to use the epidemiologic ap-  
proach and method, namely, an evaluation of all the  
definable aspects of the interaction between the  
agent (laser beam), the host (man), and the enviro-  
nment involved (the laboratory and the field).

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8. BURNS TO SKIN BY MILLISECOND LIGHT PULSES. W. L. Derksen, J. Bracciaventi, and G. Mixter, Jr. (Naval Applied Science Laboratory, Brooklyn, New York, Progress Report No. 1, July 6, 1964, report no. NASL9400; DASA 1532) AD 607 388

Descriptors: (Burns, Thermal radiation), (Thermal radiation, Burns), (Nuclear explosions, Burns), Simulation, Rats, Medical Research, Test methods, Flash lamps.

9. HOW DANGEROUS ARE LASERS? Leon H. Dulberger. Assistant Editor. (Electronics, Vol. 35, no. 4, Jan. 26, 1962, p. 27)

Experimenters should be wary. Exposure to direct or reflected laser beams can burn eyes. Properties that make lasers dangerous also give physicians a new surgical tool in eye surgery.

10. CENTRAL NERVOUS SYSTEM EFFECTS OF LASER RADIATION. K. M. Earle, S. Carpenter, U. Roessmann, M. A. Ross, and J. R. Hayes. (Armed Forces Inst. of Pathology, Army Medical Center, Washington, D. C., 1963, 11 p., UNCLASSIFIED REPORT) AD 612 442

Descriptors: (\*Pathology, Lasers), \*Lasers, Pathology), (\*Brain, Wounds and injuries), Central nervous system, Hair, Color, Head, Burns, Hemorrhage, Skin, Mice, Rats, Monkeys.

11. LASER IRRADIATION OF BIOLOGICAL SYSTEMS. S. Fine, R. E. Scott. Northeastern University. E. Klein. Ronwell Park Memorial Institute. (IEEE Spectrum, Vol. 1, no. 1, April, 1964, pp. 81-83)

Investigations with the laser are in progress that may more clearly illuminate living processes. Applications to problems in biology and medicine are under exploration.

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12. MEASUREMENTS AND HAZARDS ON INTERACTION OF LASER RADIATION AND BIOLOGICAL SYSTEMS. S. Fine, W. Nowak, W. Hansen, K. Hergenrother, R. E. Scott, J. Donoghue. North-eastern University, Boston, Massachusetts. E. Klein. Roswell Park Memorial Institute, Buffalo, New York. (IEEE Northeast Electronics Research and Engineering Meeting, 1964, pp. 158-159)

Studies have been carried out to determine the effects produced on interaction of relatively coherent high peak power radiation and biological systems. Interaction of the radiation results in a plume of backscattered radiation and volatilized material from the animal.

13. ACTIVITY IN RETINAL THERMAL INJURY. W. J. Geeraets and J. Burkhart. (Acta Ophthalmologica, Supplementum 76, Vol. 60, 1963)

14. THE LOSS OF LIGHT ENERGY IN RETINA AND CHOROID. W. J. Geeraets, R. C. Williams, G. Chan, W. T. Ham, Jr., D. Guerry, III and F. H. Schmidt. (A.M.A. Arch. Ophth., Vol. 64, October, 1960, p. 606)

1. Absorption of radiant energy by the fundus of rabbit and man occurs primarily in the spectral range 400 - 1,000 mμ, the peak absorption occurring at approximately 575 mμ.

2. Light absorption in the ocular media and in the fundus of the medium to darkly pigmented rabbit is surprisingly similar to that in man, making the rabbit an excellent test animal for investigation of thermal hazards to the retina.

3. It is interesting to note that peak absorption in the human pigment epithelium and choroid occurs in the same general region as that of visual pigments.

## 15. DERMATOLOGIC MANIFESTATIONS OF LASER RADIATION.

Leon Goldman. Laser Laboratories, University of Cincinnati, and Children's Hospital Research Foundation, Cincinnati, Ohio. (Federation Proc., Vol. 24, no. 1, Pt. III, January-February, 1965, pp. S-92-S-93, refs.)

Effects of single and repeated laser beams on normal and pathologic skin were studied. Destruction of skin from absorption of the incident laser beam varied with the type of laser, exit energy, and the duration area of impact. Other factors included color of keratin and amount and degree of destruction of melanin and hemoglobin. With high-energy lasers, significant destruction of tissue not colored by melanin or hemoglobin also occurred. Skin protection, especially from high-energy lasers, should be considered in safety programs for personnel. More basic studies on the effects of absorption, transmission, and reflectivity of the incident beam of existing lasers are needed.

## 16. A DESIGN FOR A COMPLETE MEDICAL LASER LABORATORY.

Leon Goldman, Peter Hornby, James Salsman.

The increasing interest in the application and use of lasers as research tools in biology and medicine has produced a definite need for the development of a special kind of laboratory. The standard laboratory now in use for medical and biological work does not have facilities available for adequate protection of personnel from laser light.

This paper lists eight safety measures for laboratory personnel as well as protection against inadvertent exposure of office personnel and people entering the laboratory.

- 1) Goldman: Dept. Dermatology, Univ. of Cincinnati, Cincinnati General Hospital.
- 2) Hornby: Laser Laboratory, Res. Foundation, Children's Hospital, Cincinnati, Ohio.
- 3) Salsman: Children's Hospital, Cincinnati, Ohio.

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17. EFFECT OF THE LASER BEAM ON THE SKIN. Leon Goldman,  
Donald J. Blaney, Dan J. Kindel, Jr., and Ernst K. Franke.  
Dr. Ing. (Journal of Investigative Dermatology,  
Vol. 40, 1963, pp. 121-122, refs.)

From preliminary studies, eye lesions of pigmented rabbits and skin lesions of pigmented areas of rabbits and man may be produced by the coherent beam of a ruby laser of only light power intensity. Dark color of the skin increases absorption of the laser beam. Eye protection of operating personnel is necessary.

18. PATHOLOGY OF THE EFFECT OF THE LASER BEAM ON THE SKIN.  
Leon Goldman, Donald J. Blaney, Dan J. Kindel, Jr.,  
Daniel Richfield, and Ernst K. Franke. University  
of Cincinnati, Ohio. (Nature, Vol. 197, Mar. 2, 1963,  
pp. 912-914)

Brief description of the results on preliminary experiments of the effect of the laser on the skin, using a solid-type laser with ruby crystal. The skin specimens examined include white skin of rabbits and man, colored skin of animals and man, pigmented baso-squamous papillomas, superficial haematomas in the skin of man, and white skin of man covered with lamp black, India ink, tars, and colored dihydroxyacetone. Preliminary investigations show that superficial destructive lesions may be produced in the skin of man. The more intense the coloring of the skin, the deeper the reaction. Deep necrotic lesions are produced by the lasers in pigmented areas of the rabbit ear.

19. PROTECTION OF PERSONNEL OPERATING LASERS. Leon Goldman.

Professor of Dermatology, College of Medicine,  
Univ. of Cincinnati, Director of Dermatology,  
Cincinnati General Hospital and Children's  
Hospital, and Director of Laser Laboratories,  
Cincinnati General Hospital and Children's  
Hospital, Cincinnati, Ohio. (The American Jnl.  
of Medical Electronics, October-December, 1963,  
pp. 335-338, 9 refs.)

In the rapid and fascinating development of laser research, work on the biologic aspects has lagged far behind. There has been much speculation about its prospects in biology and medicine, but actually, little work has been done—especially on man. Lack of information is of great concern because of the increasing number of physicists, electronic engineers, laboratory personnel and military personnel working with lasers, as laboratory tools.

20. ELECTRONICALLY PULSED LIGHT SOURCE FOR THE PRODUCTION OF RETINAL BURNS. W. T. Ham, Jr., R. C. Williams, R. S. Ruffin, F. H. Schmidt, H. A. Mueller, DuPont Guerdy, III, W. J. Geeraets. (To be published in Medical Electronics)

21. FLASH BURNS IN THE RABBIT RETINA AS A MEANS OF EVALUATING THE RETINAL HAZARD FROM NUCLEAR WEAPONS. W. T. Ham, Jr., H. Wiesinger, F. H. Schmidt, R. C. Williams, R. S. Ruffin, M. C. Shaffer and D. Guerdy, III. (Am. J. Ophth., Vol. 46, no. 5, Pt. I, November, 1958, pp. 700-723, refs.)

This investigation was initiated to obtain additional data in the laboratory on the production of thermal lesions in the rabbit retina.

22. OCULAR EFFECTS OF LASER RADIATION PART I. W. T. Ham, Jr., et al. (Virginia University, Richmond, Medical College, Contracts DA-49-146-XZ-102, DA-49-193-MD-2241, 1964, 33 pp., UNCLASSIFIED) AD 451 905

Descriptors: (\*Retina, Burns), (\*Eye, Lasers), Rabbits, Light, Thresholds (Physiology), Tissues (Biology), Radiation effects, Radiation hazards, Temperature, Wounds & injuries.

23. OPTICAL MASERS (LASERS). William T. Ham, Jr., R. C. Williams, W. J. Geeraets, R. S. Ruffin and Harold A. Mueller. Department of Biophysics and Biometry and Department of Ophthalmology, Medical College of Virginia. (Acta Ophthalmologica, Supplementum 76, Vol. 60, 1963, pp. 60-78, refs.)

The purpose of this paper is threefold: (1) To give a brief and elementary discussion of the ruby laser, (2) to describe some preliminary experiments with a ruby laser and its associated optical equipment as designed to produce thermal lesions of size and shape comparable to those produced by other methods in this laboratory, (3) to present current data obtained from research on retinal burns which can be useful in the evaluation of ocular hazards from lasers.

24. ANATOMIC AND HISTOCHEMICAL CHANGES IN SKIN AFTER LASER IRRADIATION. E. B. Helwig, W. A. Jones, J. R. Hayes and E. H. Zeitler. U. S. Armed Forces Inst. of Pathology, Washington, D. C. (Federation Proceedings, Vol. 24, no. 1, pt. 3, (Suppl. 14), Jan-Feb., 1965, pp. S-483-S591)

The effect of ruby-laser radiation on the skin of pigs is discussed. Anatomical changes and detailed histological effects are described. The enzyme-activity changes in the affected tissues were also studied.

A comparison of laser lesions to thermal injury in pig skin indicates that thermal events can explain the lesion without bringing other physical effects into play.

25. EFFECTS OF HIGH-POWER GREEN LASER RADIATION ON CELLS IN TISSUE CULTURE. Fred M. Johnson. Electro-Optical Systems, Inc. Robert Olson, Donald E. Rounds. Pasadena Foundation for Medical Research, Calif. (Nature, Vol. 205, no. 4972, Feb. 13, 1965, p. 721)

The availability of high-power, coherent radiation at new wave-lengths, by means of non-linear optics, has made possible new experiments in the field of radiation effects on cells in tissue culture. It has been shown, by exposure of melanin granules to ruby radiation at 6943 Å and its harmonic at 3471 Å, that injury sustained by cells in tissue culture is strongly dependent on wavelength. This confirmed the observations by Bessis et al, that erythrocytes were destroyed by ruby laser radiation while unstained leucocytes were not affected. In the work reported here, a variety of cell types were irradiated with power density at this wave-length in the range of 0.05-100 MW/cm<sup>2</sup> to observe their response.

26. THE BIOLOGICAL ASPECTS OF LASER RADIATION. E. Klein. Dept. of Dermatology, Roswell Park Memorial Inst., Buffalo, N. Y. S. Fine. School of Engineering, Northeastern Univ., Boston, Mass. (Presented at the 149th Meeting, Am. Chemical Soc., Detroit, Mich., April 4-9, 1965)

Studies on effects of relatively coherent, monochromatic laser radiation, (as available from lasers) were carried out on biological macromolecular preparations, isolated cells, organ preparations, and intact and tumor bearing animals. Exploration of laser effects in man included studies of retinal coagulation and irradiation of benign and malignant skin lesions.

Hazards of laser radiation included effects on skin and deeper structures. Potential hazards of reflected and back-scattered radiation in addition to the dangers of direct exposure were indicated.

27. AN EXPERIMENTAL LASER RETINA COAGULATOR. C. J. Koester. and E. Snitzer. Research Dept., American Optical Co., Southbridge, Mass. C. J. Campbell and M. C. Rittler. Dept. of Ophthalmology, Columbia U., New York, N. Y. (A paper presented at the Washington Meeting of the Optical Society of America, Mar. 17, 1962)

Retina coagulation by means of an intense beam of light is now a well established medical procedure. Prof. Meyer-Schwickerath in his pioneering work used first the sun as the source, later the carbon arc, and more recently the xenon lamp. One application of the technique is in the management of detached retinas. The technique is also useful in treating tumors on the retina. The advantages over conventional surgery are that 1. opening the globe and the danger of infection is eliminated and 2. in treating through the pupil, the physician can also examine through the pupil and thereby have the best possible control of the area to be treated.

28. EFFECTS DUE TO ABSORPTION OF LASER RADIATION. J. F. Ready. Honeywell Research Center, Hopkins, Minnesota. (Optical Society of America, 1963, Spring Meeting Program, p. 11)

A Theoretical model for the effects of absorption of a high-power pulse of laser radiation at an opaque surface has been developed. The model utilizes solutions of the one dimensional equation for heat flow and a phenomenological treatment of the emission of vaporized material from the surface to predict the effects expected as functions of the properties of the absorbing material and of the parameters of the laser pulse. Qualitatively, the magnitude of the effects increase as the duration of a pulse of constant energy decreases (as peak power increases) and increase as thermal conductivity of the absorber decreases. The quantities calculated include the amount of material vaporized and the impulse delivered to the absorbing surface.

29. **THE EFFECT OF LASER ENERGY ON CELLS IN TISSUE CULTURE.**  
D. E. Rounds. (Pasadena Foundation for Medical Research, California, Annual Progress Report 1 Feb.-31 Jan., 1965, Contract DA-49-193-md-2564, 27 Nov., 1964, 6 pp., UNCLASSIFIED) AD 452 378

Descriptors: (\*Lasers, Radiation effects),  
(\*Tissue culture cells, Radiation effects),  
(\*Radiation effects, Tissue culture cells), Cells.  
(Biology), Synthesis, Pigments, Lungs, Reptiles,  
Mitosis, Enzymes, Inhibition, Cytoplasm, Desoxyri-  
bonucleic acids, Chromosomes, Ultraviolet radiation,  
Wounds & injuries, Mitochondria, Morphology (Biology),  
Absorption, Sensitivity.

30. **THE DARK SIDE OF THE LASER.** J. J. Schlickman and R. H. Kingston. Lincoln Laboratory, Mass. Inst. of Technology, Lexington, Mass. (Electronics, April 19, 1965, pp. 93-98, refs.)

The direct beam of a laser can cause severe eye damage. So can reflected beam, even when the reflecting surface is not mirror bright. Cases of temporary blindness have been reported by a number of researchers and efforts have been made to reduce the hazard.

A dosimeter that measures the energy of a reflected laser pulse has been developed as a safeguard against eye damage. Readings of the dosimeter will tell when the radiation has reached the danger level. Data obtained from experiments on eye damage in rabbits was used to develop and calibrate the laser dosimeter.

31. **LASERS AND THE EYE.** Deamond Smart. (New Scientist, Vol. 26, no. 445, May 27, 1965, pp. 570-572)

The same properties that are making the laser steadily more useful in the hands of a surgeon are making them more hazardous to the unwary.

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32. OCCUPATIONAL SAFETY WITH LASER (OPTICAL MASER) BEAMS.

Leonard R. Solon. Radioptics, Inc., 28 Pilgrim Ave., Yonkers, N. Y. (Arch. Environmental Health, Vol. 6, March, 1963, pp. 120-123)

Experiments have been performed at New York University which have confirmed in animal experiments the retinal hazard which may occur during the use of lasers. Four practical guidelines for the occupational safety specialist in protecting laboratory and plant personnel, are given.

33. PHYSIOLOGICAL IMPLICATIONS OF LASER BEAMS.

Leonard R. Solon, Raphael Aronson, Gordon Gould. (Science, Vol. 134, no. 3489, Nov. 10, 1961, pp. 1506-1508)

Development of molecular amplifiers in the visible and near-visible region (1) of the electromagnetic spectrum has been in progress at several laboratories. Such amplifiers go under the designation of "laser" or optical maser, the former term being an acronym for light amplification by stimulated emission of radiation. Such devices have been successfully demonstrated at several places (2), and several industrial organizations have made them available commercially. It is almost certain that lasers will be incorporated into communications and other technologies at a rapid rate. This article presents some preliminary calculations which are of physiological interest in terms of the hazard associated with laser beams and their potential employment as biological and clinical tools.

34. THE USE OF LASER BEAMS AND THEIR POTENTIAL OCCUPATIONAL HAZARDS. L. Solon. (Industrial Hygiene Rev., 5, May, 1962, pp. 19-26)

35. **FLASH BLINDNESS AS A FUNCTION OF WAVELENGTH SPECIFICITY.**  
H. G. Sperling. Honeywell Incorporated, Minneapolis.  
 Minnesota. (Federation Proceedings, Vol. 24, no. 1,  
 Pt. III, January-February, 1965, pp. S-73-S-77, refs.)

Data are reported on the effects of adaptation to spectral bands of light on human foveal spectral sensitivity. These show that where very narrow adapting bands in the upper range of intensities of normal vision are used, extreme changes in the shape of the function result. This finding indicates that sensitivity might be preserved in parts of the spectrum, while permitting continuous viewing through special eye-protective filters. The results further indicate an approach to isolating the spectral response components of normal color vision and the magnitude of their response to light adaptation.

36. **PROTECTION OF THE HUMAN EYE FROM LASER RADIATION.**  
Harald W. Straub. (Harry Diamond Labs., Washington,  
 D. C., Proj. AO260, 10 July 1963, 15 p.) AD 415 740L

Descriptors: (\*Burns, Retina), (\*Retina, Burns),  
 (\*Lasers, Radiation effect), Optical filters, Eye,  
 Eyeglasses.

37. **USE OF PROTECTIVE GOGGLES IN AREAS OF LASER RADIATION.**  
Harald W. Straub. Harry Diamond Laboratories,  
 Washington, D. C. (Federation Proceedings, Vol.  
 24, no. 1, Pt. III, January-February, 1965, pp.  
 S-78-S-79)

Energies generated by ruby, neodymium, and gallium arsenide laser pulses are sufficient to produce permanently blinding retinal burns in the human eye. It is therefore, imperative that personnel operating in areas of laser activity wear suitable protective goggles. Devices triggered into the "shut" state by the oncoming pulse must be considered unsafe, especially those developed against nuclear flashes. This also applies to most fixed devices, the spectrally selective filters, and mirrors. The only notable exception is the Jena color glass BG-18, effective against both the ruby and neodymium laser.

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38. EYE PROTECTION AGAINST LASERS. C. H. Swope and C. J. Koester. American Optical Company, Southbridge, Massachusetts. (Applied Optics, Vol. 4, no. 5, May, 1965, pp. 523-526, refs.)

From published data on threshold dosage for an observable retinal lesion, calculations were made on the attenuation required to protect the human eye against pulsed laser radiation. A solution to this problem which provides eye protection against an Nd-doped glass laser delivering up to 740 J in an impact area 5 mm in diameter on the filter is described. Finally, several suggestions are made for protecting the eyes of personnel working with lasers.

39. SAFETY CONSIDERATIONS OF LASERS. Michael Sykos. (Journal of the American Society of Safety Engr., Vol. VIII, no. 4, April, 1963, pp. 14-18, refs., also Univ. of California, Ernest O. Laurence Radiation Laboratory, Rept. no. UCRL-7193, Jan. 14, 1963, 15 p.)

The laser- a new device dubbed the "death ray" by the military and hailed as a modern "Aladdin's lamp" by other researchers - is one of the hottest items to enter the industrial scene. In addition to its advantages, it brings to the user a variety of hazards that can cause serious injury. This paper describes the operation of lasers, summarizes laser applications, and describes laser hazards and their controls.

40. **LASER - MEDICAL AND INDUSTRIAL HYGIENE CONTROLS.**

H. E. Tebrock, W. N. Young, and W. Machle.  
(J. Occupational Med., Vol. 5, 1963, pp. 564-567, refs.)

The principles of controlling environmental laser hazards are as follows:

- 1) Avoidance of principal beam and its reflection
- 2) Proper education of personnel involved
- 3) Use of warning devices to indicate laser operation
- 4) Use of proper antilaser eyeshields on any observer likely to be exposed
- 5) Reporting of all persistent after-images
- 6) Fundoscope and slit-lamp examination of all people involved in laser operations

41. **NON-THERMAL BIOLOGICAL EFFECTS OF LASER BEAMS.**

Victor T. Tomberg. Biophysical Research Laboratory, and New York School of Medicine. (Nature, Vol. 204, no. 4961, November 28, 1964, pp. 868-870, refs.)

Investigating the effects of pulsed and continuously emitting lasers, we were able theoretically and experimentally to establish that non-thermal effects exist which have to be considered biologically more important than the thermal effects, such as the discrete coagulation of tissue which is therapeutically used, for example, in eye surgery.

We calculated that the laser field has an important electrical vector which has to be considered responsible for causing biological effects of the following classification: (a) thermal; (b) specific-thermal; (c) specific-electric; (d) chemical; (e) kinetic.

42. **THE TRANSMISSION OF LIGHT THROUGH THE OCULAR MEDIA OF THE RABBIT EYE.**

H. Wiesinger, F. H. Schmidt, R. C. Williams, C. O. Tiller, R. S. Ruffin, U. Guerry, III and W. T. Ham, Jr. (Am. J. Ophth., Vol. 42, 1956, p. 907)

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43. LASER PHOTOCOAGULATION OF THE EYE. M. M. Zaret,  
H. Rippe, I. M. Siegel, and G. M. Breinin.  
(A. M. A. Arch. Ophth., Vol. 69, Jan. 1963,  
p. 97)
44. OCULAR LESIONS PRODUCED BY AN OPTICAL MASER (LASER).  
Milton M. Zaret, Goodwin M. Breinin, Herbert Schmidt  
and others. (Science, Vol. 134, no. 3489, Nov. 10,  
1961, pp. 1525-1526, also, Optical Maser Symposium,  
1961)
- Ocular lesions have been experimentally produced in rabbit by a pulsed optical maser (laser). The high-energy density delivered in a single 0.5 msec pulse was sufficient to cause instantaneous thermal injury to the pigmented retina and iris of the brown rabbit. Ophthalmoscopically, the retinal lesions resembled flash burns from an atomic fireball.
45. MORE LIGHT ON LASERS. (Electronics, Vol. 38, no. 6,  
Mar. 22, 1965, pp. 128-133)
- Researchers sound a warning on harmful effects of laser irradiation and urge users to take safety measures.
46. LASERS AND MASERS: (Accident Prevention Dept.,  
Assoc. of Casualty and Surety Companies, New  
York, N. Y., Special Hazards Bulletin, no. Z-125,  
May, 1963)
- This bulletin lists eleven precautionary measures that could be taken in the laser laboratory.
47. RADIATION THRESHOLDS FOR CHORIORETINAL BURNS.  
(Aerospace Medical Division, 6570th Aerospace  
Med. Res. Lab., Wright-Patterson Air Force Base,  
Ohio, 1963, Rept. AMRL-TDR-63-71)

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48. THE RELATIVE ABSORPTION OF THERMAL ENERGY IN RETINA  
AND CHOROID. (Invest. Ophth., Vol. 1, June, 1962,  
p. 340)